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TECHNICAL NOTE

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A TIME SHARING SWITCH FOR SPACECRAFT TELEMETRY SYSTEMS

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SUMMARY

Where there are low signal levels or when long life is required in a spacecraft's telemetry system, the application of mechanical commutators usually is not considered because of the inherent wear and the resultant electrical degradation which ordinarily is present in mechanical systems.

In the development of the TIROS infrared instrumentation a mechanical commutator capable of time-sharing low signal levels for long periods of time was designed. This mechanism requires little driving torque, is small in size, and is light in weight.

This paper describes this particular commutator, demonstrates its feasibility, and indicates possible adaptations which will enable it to satisfy various requirements.

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INTRODUCTION

In the design of spacecraft telemetry systems it frequently is convenient to time-share items of data onto a single channel of a suitable storage or transmission medium. Electronic commutators are used for this purpose where features such as low signal levels, high data rates, and long life are required. Ordinary mechanical commutators are used where low data rates are required, but they are usually limited to applications involving medium signal levels. Furthermore, the lifetimes of ordinary mechanical commutators are usually limited. However, the time sharing switch (TSS) discussed in this paper operates reliably with low signal levels (about 20 microamperes, 0.05 microvolts, 450 cps) for long periods of time. In addition, this TSS rivals the ordinary mechanical commutator in low driving torque (0.0005 inch-ounce at 256 rpm), accurate timing, small size, and low weight.

The time sharing sequence is obtained basically by stacking microswitches to face one or more cams. The cams are driven through a gear box located beneath the banks of switches, and levers are used to transform the rotary motion of the cams into a linear motion necessary to depress the microswitch plungers.

Successful operation of the TSS has been demonstrated in the TIROS II satellite's infrared instrumentation, where it was used to cycle data from twelve separate sensors onto a channel of the infrared tape recorder. This TSS was still operating satisfactorily six months after launch.

The TSS is composed of two assemblies: the lever-switch assembly and the transmission assembly. These will be discussed separately. The relative positions of the switches, levers, and cams can be seen in Figure 1. All magnesium parts in the TSS

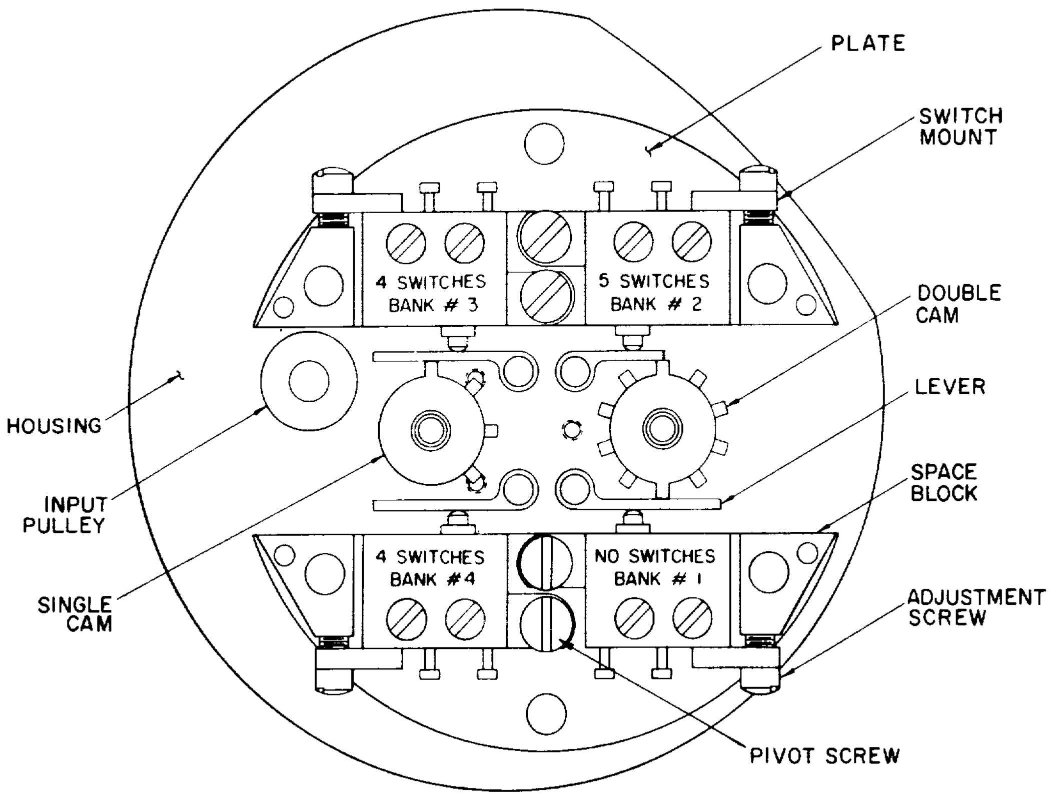

Figure 1 - Cutaway view of the entire assembly of the time sharing switch showing the relative positions of the switches, levers, and cams. (In the particular unit discussed, bank 1 has no switches and hence no levers.)

are coated with Dow - 7, all bearings are stainless steel, and all screws are captivated by Glyptal.

LEVER-SWITCH ASSEMBLY

The lever-switch assembly includes the levers, microswitches, and supporting structure.

The levers, which transform the rotational motion of the cams into a linear motion necessary to depress the switches, are magnesium plates pivoted at one end and kept lined up with the cam lobes by spacers on the pivot shafts. Each of the four pivot shafts in the space between the cams is able to hold five levers. Along with each pivot shaft there is a bank of switches; and on each shaft there are as many levers as there are switches in the corresponding bank. Where there is no switch on a particular level of a given bank, the corresponding lever is replaced by a spacer on the pivot shaft. Figure 2

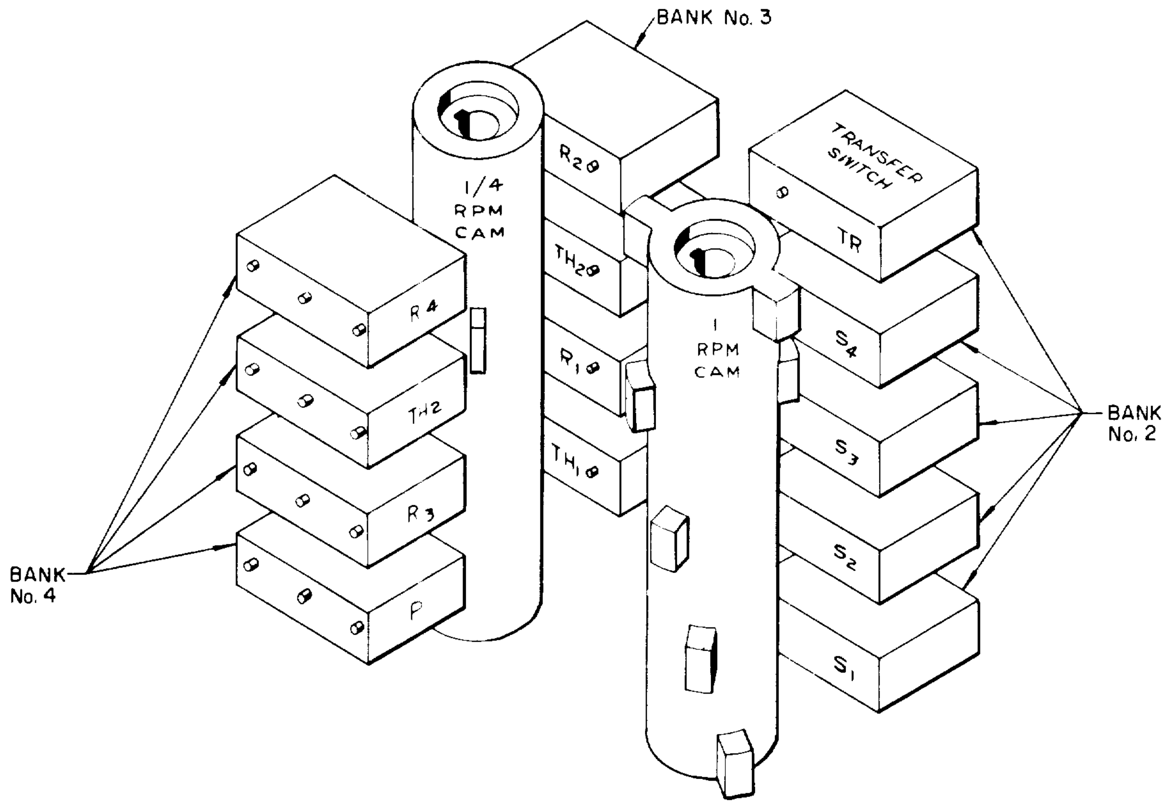

Figure 2 - Stacking arrangement of the time sharing switch

shows the stacking arrangement: the banks numbered 1 (not shown) and 2 face each other on opposite sides of the double cam and banks numbered 3 and 4 face each other on opposite sides of the single cam. (The banks are numbered counterclockwise when observed from the top.) For the particular unit discussed here, there are no switches, and therefore no levers, in bank 1; five switches and levers in bank 2, and four in banks 3 and 4.

The switches used in the TSS are Minneapolis-Honeywell subsubminiature micro-switches. Because of space limitations, they must be modified in two ways:

1. The mounting holes are countersunk to take flat head screws.
2. The contact marked NC is cut off and filed smooth.

The TSS supporting structure consists of five layers of magnesium plates separated by aluminum spacers. (Each plate has a capacity of two switches; therefore, two plates are needed in each layer in order to hold four banks.) One stack of plates and spacers holds banks 1 and 4 while the other stack holds banks 2 and 3. The plates are semi-circular in shape, with a radius of 1 inch. They are cut away along a line perpendicular to their line of symmetry to allow room for the cams and levers.

There are three spacers on each plate: one at each corner and one at the outer edge along the line of symmetry. The two types of spacers used are (1) cylinders and (2) truncated triangular prisms called space blocks. The latter are used at the corners of the plates where the switches are mounted; all other spacers of the structure are the cylindrical type.

The upper mount, which is a 2-inch-diameter circular magnesium plate, supports the switch lever shafts, bearings for the cam shafts, and six screws which go through the spacers and plates and screw into the housing. These stainless steel screws hold the entire assembly together.

The microswitches are supported in this structural framework by means of the switch mounts, shown in Figure 3 (see also Figure 1). These mounts are magnesium plates with two tapped holes for mounting the microswitches, a hole with a stainless steel bushing for a pivot screw, and a perpendicular segment with a clearance hole for an adjustment screw which screws into the space block. The position (and therefore the timing) of each switch is adjusted by placing shims between the protrusion and the space block.

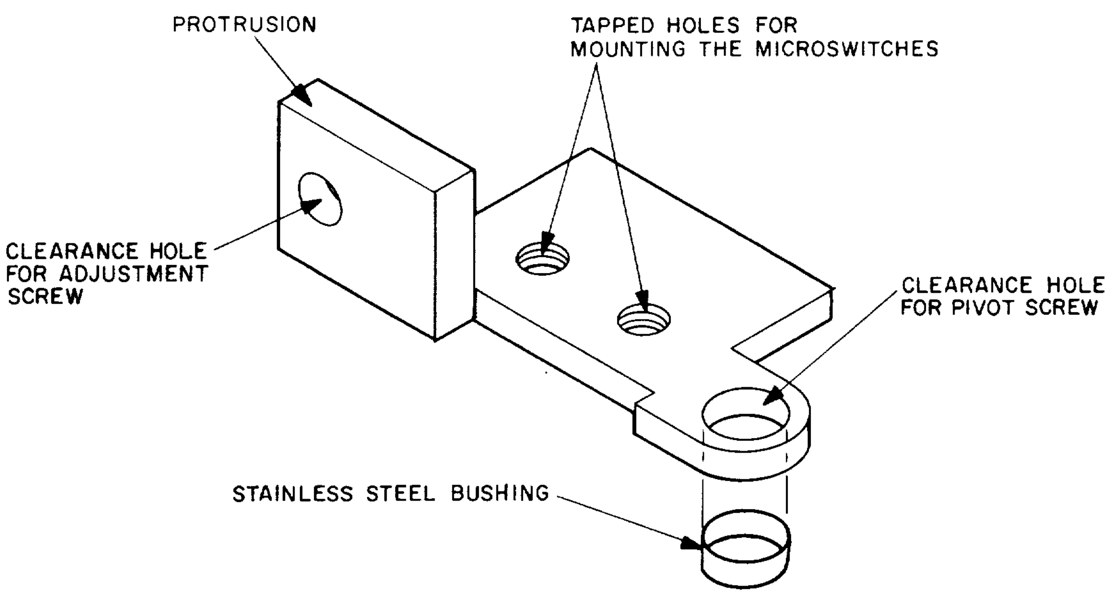

Figure 3 - Switch mount

TRANSMISSION ASSEMBLY

The transmission assembly includes the input pulley, gear reduction and housing, and the cams.

The input pulley, driven by a 1-mil Mylar belt 1/16 inch wide, is aluminum and operates at 256 revolutions per minute.

The gear reduction consists of six gears, five pinions, and the shafts, all made of type 303 stainless steel.

The magnesium housing of the gear train resembles a hat, being cylindrical in shape with a large flange on top. A round magnesium plate is screwed into the bottom of the housing to close it off. This plate and the top of the housing encompass the entire gear train.

The double cam, fastened to its shaft by means of a key and a snap ring, is made of Kel-F and is cylindrical in shape. There are two protruding lobes (Figure 2) 180 degrees apart on each of five separate levels similar to a spiral staircase. The lobes on each level are displaced from those on the level below by 36 degrees, in an arrangement resembling a spiral staircase. This cam rotates at 1 revolution per minute. The single cam is made in the same way, but has only one lobe (Figure 2) on each of four levels, spaced 45 degrees apart. This cam rotates at 1/4 revolution per minute.

OPERATION

The TSS contains four switch banks of which, in this particular unit, only three are used. Bank 1 contains no switches, bank 2 has five, and banks 3 and 4 both contain four switches. The switches are designated (Figure 2) as follows (beginning with the bottom of each bank):

Bank 2: S_1, S_2, S_3, S_4, TR

Bank 3: TH_1, R_1, TH_2, R_2

Bank 4: P, R_3, TH_2, R_4

The double cam rotates at 1 revolution per minute; and the spacing of the switches, levers, and cam lobes is such that each switch in bank 2 is closed for about 6 seconds per operation. The single cam rotates at 1/4 revolution per minute, and each switch in banks 3 and 4 is closed for about 30 seconds per revolution. As is shown in Figure 4, each switch is slowly depressed to a maximum point (A), held there for several seconds and quickly released at B. This quick release is caused by the short levers in bank 2, D-1172

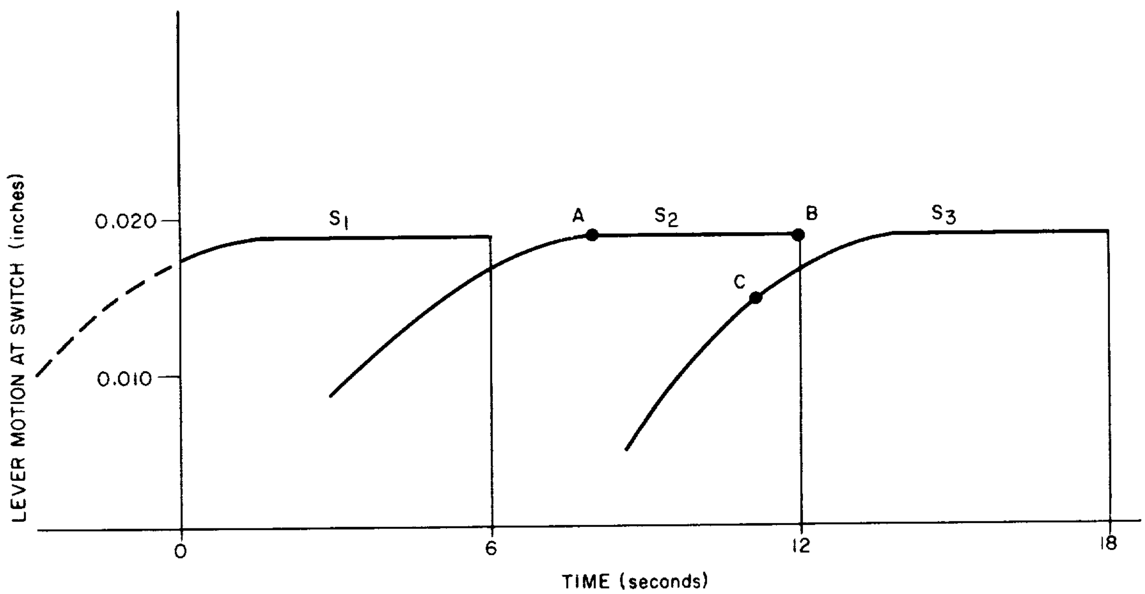

Figure 4 - Lever travel as a function of time

and occurs every 6 seconds regardless of the actual time settings of the microswitches. The time between A and B is determined by the width of the cam lobe. Point C is representative of that point where the next microswitch is closed; for this particular TSS, there is an overlap between switching operations (C occurs before B).

Figure 5 shows the position of the microswitches in bank 2 with respect to the cams, and is useful for demonstrating the method of adjustment. The switch mounts are pivoted at P by means of a pivot screw and a clearance hole. An adjustment screw goes through a hole in the protrusion of the switch mount (Figure 3) and screws into the space block (Figure 1). The switch is positioned closer to or farther from the cam by placing shims (thin washers) between the protrusion and the space block. The position of the switch with respect to the cam determines point C in Figure 4, and thus permits adjustment of the time that the switch is closed.

As shown in Figure 6, switches S_1, S_2, S_3, and S_4 in bank 2 are wired individually, and the transfer switch is wired in series with all the switches in banks 3 and 4. This gives the following cycle of operation:

S_1, S_2, S_3, S_4, TH_1, S_1, S_2, S_3, S_4, R_1, S_1, S_2, S_3, S_4, TH_2,
S_1, S_2, S_3, S_4, R_2, S_1, S_2, S_3, S_4, P, S_1, S_2, S_3, S_4, R_3, S_1,
S_2, S_3, S_4, TH_2, S_1, S_2, S_3, S_4, R_4.

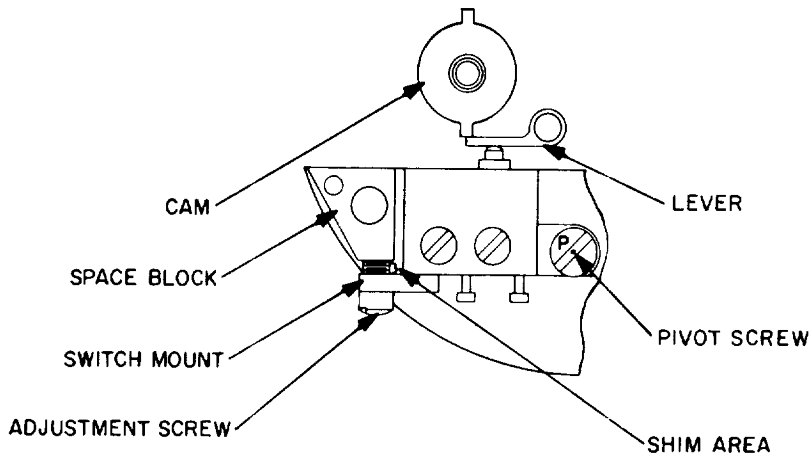

Figure 5 - Switch adjustment

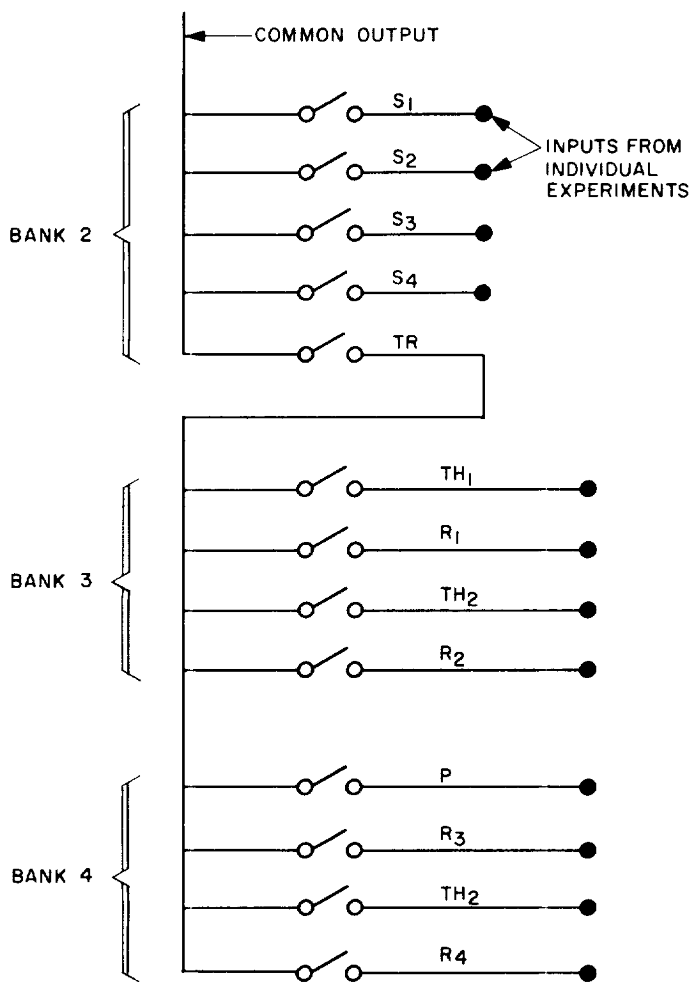

Figure 6 - Circuit of the time sharing switch

Since all the switches in bank 2, including TR, are closed for only about 6 seconds, each reading for banks 3 and 4 also lasts for approximately 6 seconds, with about 1/2 second overlap between switching operations.

TESTING

The TSS has successfully passed the following environmental tests:

Vibration: The TSS has been tested by both sinusoidal and random vibration. In the sinusoidal vibration tests it survived 20 g zero-to-peak at 0 to 2000 cps in a 45 minute sweep in each of three mutually perpendicular directions. In the random vibration tests it survived 20 g rms, in the range 20 to 2000 cps for 3 minutes in each of three mutually perpendicular directions.

Thermal: The TSS was kept at temperatures of 0°C and 60°C for more than 3 days at each temperature with only slight changes in its mechanical performance.

Life: The TSS was run in an accelerated life test equivalent to 15 months of normal operation. During the tests, a limited amount of wear occurred on the cams, levers, and microswitch plungers; however, the wear was acceptable. It should be noted that no lubricant has been applied to the cams or levers.

MODIFICATIONS

The TSS has a definite amount of flexibility in its design and it can be adapted to perform many different types of switching functions. Some possible modifications are:

1. Microswitches may be added or subtracted to give the desired number of readings in a given time.

2. The input speed may be varied to give the desired time for a switch cycle.

3. The size, number, and position of the cam lobes may be varied to alter the length of time each switch operates, the number of times each switch operates per cam revolution, and the phase of the switching operation.

4. Because of the gear reduction between cams, one or more transfer switches may be employed, as has been done in the TSS for the infrared experiments in the TIROS satellites.

The modifications just listed represent only minor modifications to the basic TIROS design and by no means exhaust the list of possible modifications. For example, it is also possible to stack the switches in other arrangements, to use different cam diameters, larger switches, etc., and still retain most of the performance qualities of the basic TSS.

ENGINEERING DISCLOSURES

During the development and testing of the TSS, the following items of general engineering interest were discovered:

1. Before the TSS was designed, a life test had been run on several microswitches. The test setup included a cam driven by a synchronous motor, a lever, and a microswitch being tested. The microswitch was wired to a power supply and a pen recorder, thus permitting readout without constant personnel monitoring. The test jig enabled the switches to be positioned, with respect to the cams, within 0.0001 inch. The results of this test indicate that the switch life depends on the amount of overtravel used. (Overtravel is defined as the distance the switch plunger travels beyond the point at which the contacts close.) Switches mounted so that the plunger motion used up all the overtravel failed after about 200,000 operations; but when other switches were mounted so that some overtravel was left, the test was terminated after 1,000,000 operations without failure. Thus, all failures occurred when the overtravel was completely taken up; and all failures were caused by spring fatigue. The microswitches now in use are equipped with stops to limit the overtravel.

2. Set screws cannot be used to fasten the Kel-F cams to the shafts because they distort the cams, reducing the timing accuracy. Keys and lock rings have been found satisfactory.

3. When sub-subminiature switches are used in a mechanism which causes a very slow motion of the switch plunger, a high electrical resistance often occurs just prior to the reopening of the contacts. This problem was eliminated from the TSS for TIROS II in two ways:

   (1) The switches in banks 3 and 4 are wired in series with the transfer switch (see Figure 6). Because the switches in banks 3 and 4 are closed for approximately 30 seconds per operation and the transfer switch in bank 2 is closed for only 6 seconds, a high resistance occurring at the end of any single operation in banks 3 or 4 is never recorded.

   (2) The switches in bank 2 cause their respective experiments to be recorded during the total operational (closed) time of each switch. If the high resistance were encountered in a switch in bank 2, therefore, it would cause an incorrect reading to be recorded. To overcome this problem, short levers were introduced

in bank 2. As will be seen in Figure 5, the length of these levers is such that the cam will release the contacts quickly. This quick opening precludes the high resistance and thus permits optimum operation of the switch.

4. An extensive study which lasted several months revealed a problem peculiar to the TSS. The problem was discovered while the TSS was undergoing a thermal test at 60°C. After about 12 hours of satisfactory operation, some of the resistance readings measured across the microswitches in banks 3 and 4 became erratic. It was found that the Loctite which had been used to hold the microswitches onto the switch mounts caused the trouble. Loctite hardens only when it is contained; while it is exposed to air, it remains liquid. When the test was performed at 60°C, the unhardened Loctite vaporized inside the microswitches and condensed on the contacts. The contacts closed for 30 seconds at a time, and this was enough to permit a small amount of Loctite to harden. The current in the switches was too low to burn off the Loctite and therefore, after a number of operations, erratic readings began. By captivating the screws near the microswitches with Glyptal, the problem no longer existed.

ACKNOWLEDGMENTS

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